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(54) Tunnel magnetron for cathode sputtering

(57) A tunnel magnetron source magnet arrangement including an array of magnets to provide an array of a plurality of similar, side-by-side tunnel magnetic fields, means to support the array to apply the plurality of tunnel magnetic fields at a surface of the source, means to move said array and said surface relative to one another so that the plurality of tunnel magnetic fields sweep over said surface, the arrangement being such that the movement causes said tunnel fields to sweep over substantially all the surface area and any adjacent sputtering source surface providing a plurality of simultaneous erosion zones together producing substantially uniform erosion over the whole of the sputtering source.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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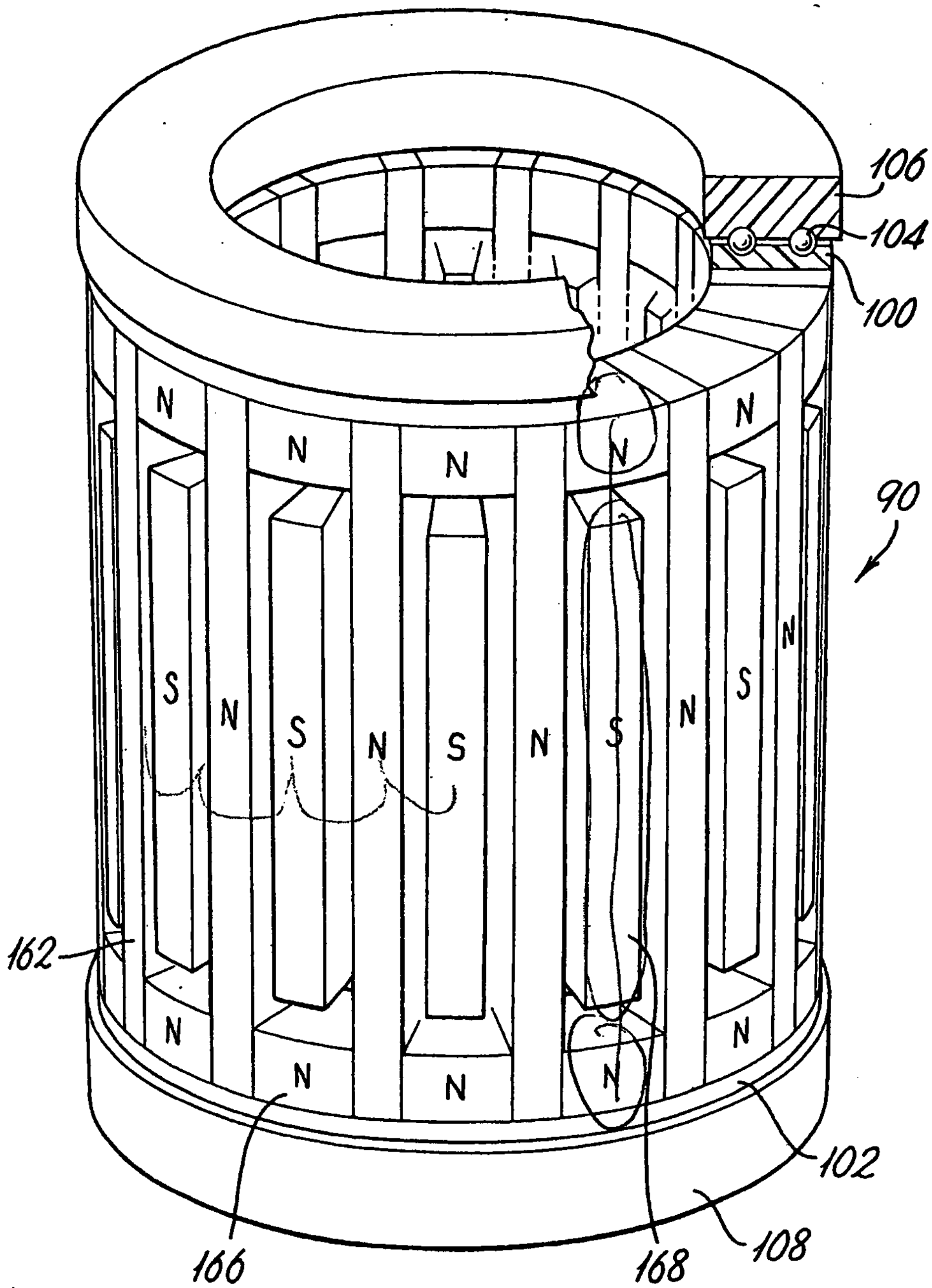

Fig. 1

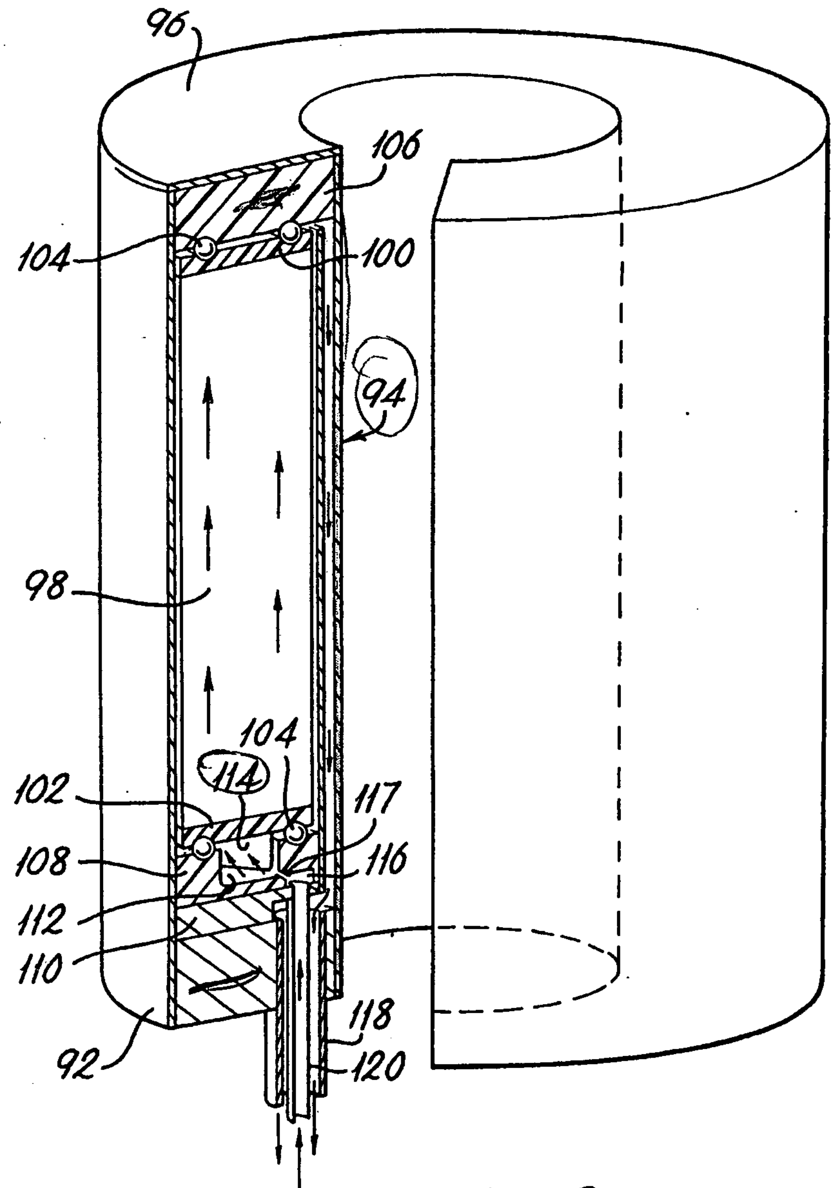

Fig. 2

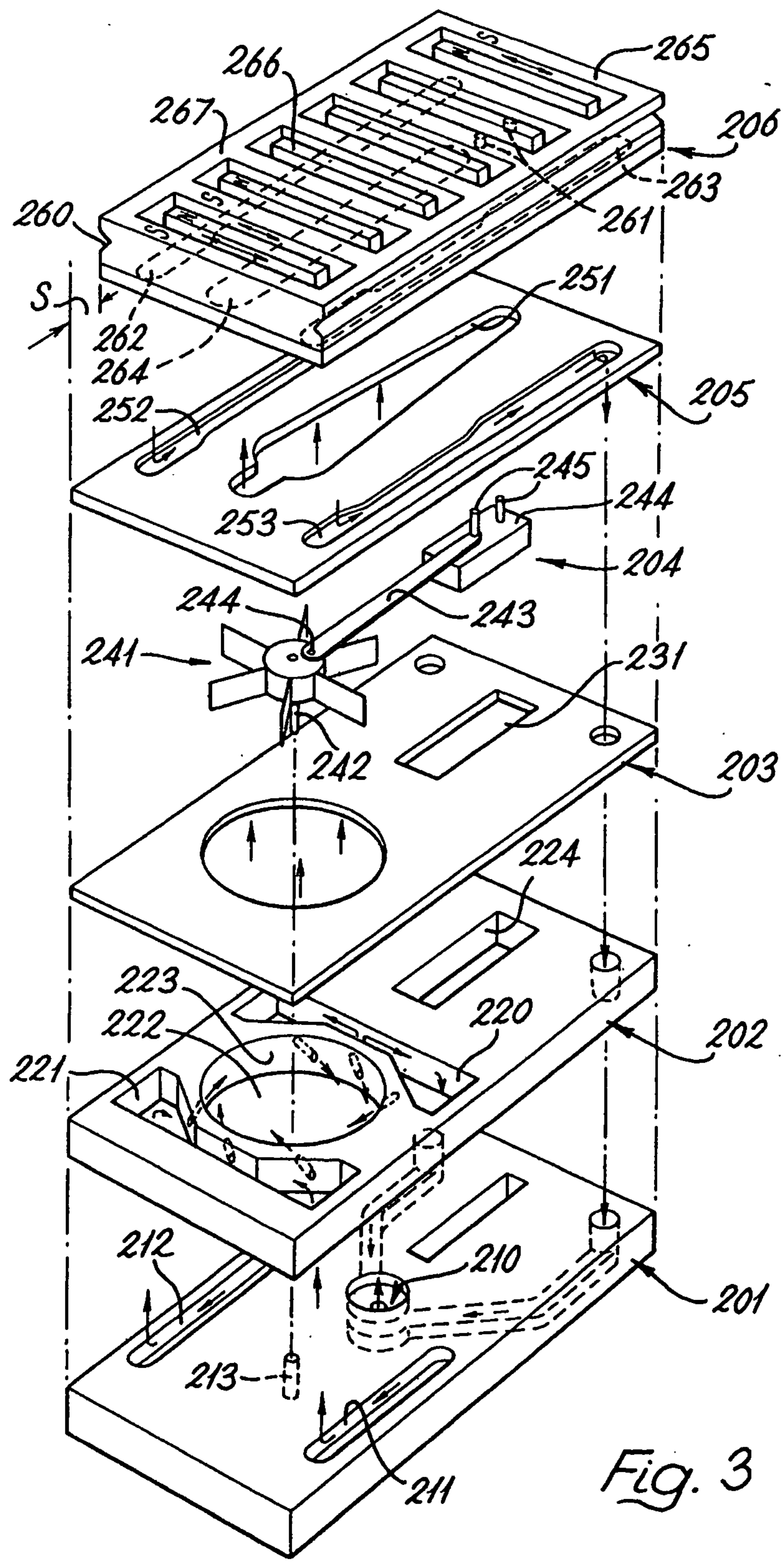
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Fig. 3

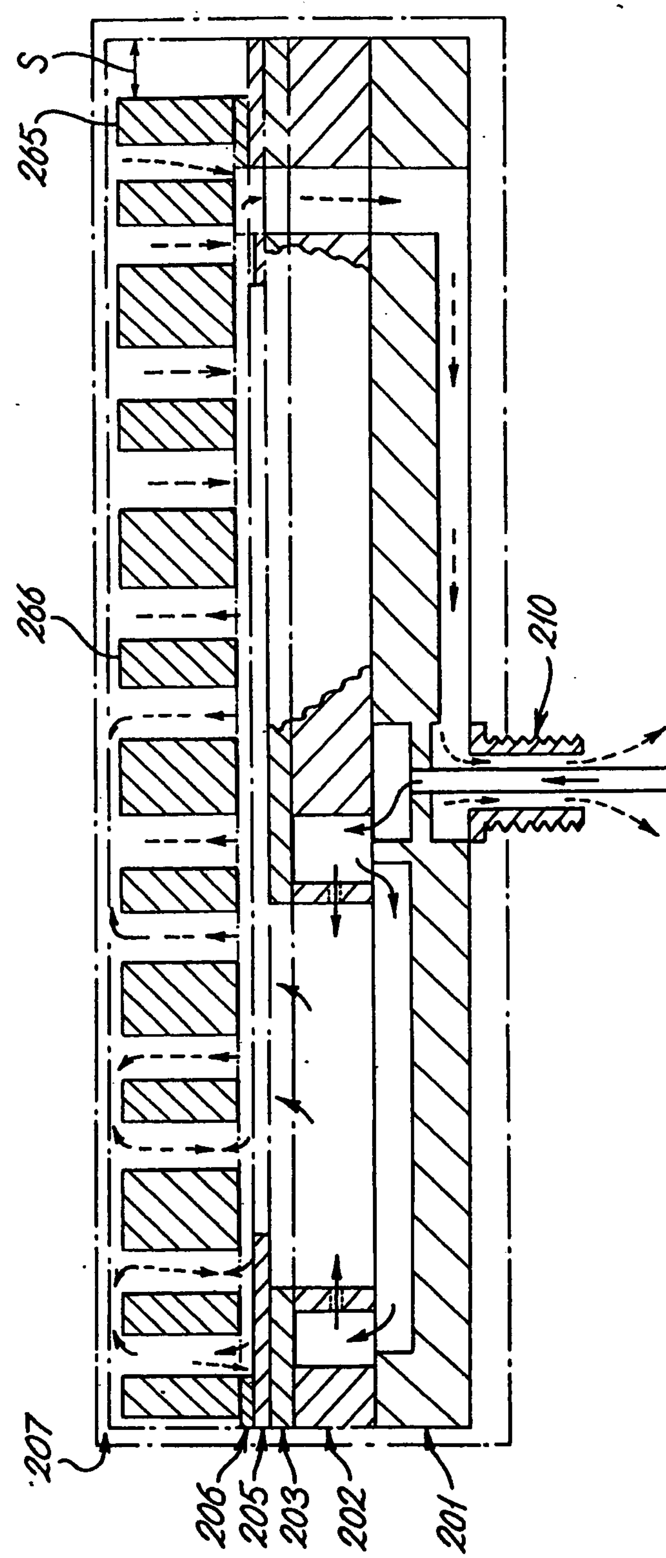

Fig. 4

SPECIFICATION

Magnetron magnet

This invention relates to magnetrons, i.e. to devices in which a gas is ionised to form a plasma which is constrained by a magnetic field and relates particularly to tunnel magnetrons in which the magnetic field lines begin and end on a plane surface to form a "tunnel" in which the ions move.

Tunnel magnetrons are described in general in a paper by L. Holland, Institute of Physics Conference Series Number 54, Chapter 6, 1980, pages 220 to 228. In Vacuum, Volume 31, 1981, pages 5 to 7, C. Elphick describes the construction of a particular type of tunnel magnetron intended for cathode sputtering and which has a planar electrode which is water cooled.

It is a disadvantage of a tunnel magnetron when used for cathode sputtering that the sputtering material is eroded only in the area coincident with the magnetic field tunnel. Thus the material, which may be expensive, is used inefficiently and deep erosion may change the sputtering conditions so that the characteristics of the sputtered film vary with time.

To overcome this disadvantage, it has been suggested that the magnet assembly forming the tunnel should moved from one part to another of the sputtering material so that the material is eroded more evenly, and a mechanical arrangement to achieve this movement is known. However the form of the erosion area varies with the sputtering material so problems still arise, a continuation of UK Patent Application.

In UK Patent Application 8220270 there is disclosed a tunnel magnetron source including an array of magnets arranged to provide magnetic field lines of at least one tunnel magnetic field at a surface of the source, and pipe means through which a cooling fluid can be supplied, the surface and the array of magnets being relatively movable so that said at least one tunnel magnetic field moves over said surface of the source, and one of the surface and the array of magnets having at least one planar vane on which the cooling fluid impinges so as to cause said relative movement.

In the present application a movable magnetron magnet arrangement providing a particular relative movement is disclosed.

According to the present invention there is provided a tunnel magnetron source magnet arrangement including an array of magnets to provide an array of a plurality of similar, side-by-side tunnel magnetic fields at a surface of the source, means to move said array and said surface relative to one another so that the plurality of tunnel magnetic fields sweep over said surface the arrangement being such that the movement causes said tunnel fields to sweep over substantially all the surface area and any adjacent sputtering source surface providing a plurality of simultaneous erosion zones together producing substantially uniform erosion over the whole of the sputtering source.

The array may be planar, such as a flat plate, or closed, such as a cylinder, in which array magnets are assembled with an alternation of polarity.

The means to move the array can be of any convenient form such as a mechanical linkage from a motor or a drive through gears or other transmission device. Electromagnetc action without contact may also be used. However it is convenient to use the cooling fluid drive technique disclosed in the above-mentioned UK Patent Application 8220270.

The whole of the plurality of fields may sweep the whole surface of the electrode, as with a cylindrical array and cylindrical electrode, or adjacent fields may sweep in turn in a reciprocating manner over adjoining and overlapping parts of the surface, each part being subject to a field substantially uniform and without interruption.

The uniform erosion may be substantially continuous over the whole sputtering source.

The invention will now be described by way of example only with reference to the accompanying drawings in which:—

Figure 1 is a view of the magnetic rotor of a first embodiment of a tunnel magnetron source,

Figure 2 is a part sectional view of the first embodiment source,

Figure 3 is an exploded a view of the magnetic array and drive arrangement of a second embodiment of a tunnel magetron source, and

Figure 4 is a part sectional view of the second embodiment source.

For convenience Figures 5 and 6 of the above mentioned Application are reproduced and described here as Figures 1 and 2.

Figure 1 shows the magnet array 90 for a first embodiment of a tunnel magnetron source. A number, say sixteen, rectangular planar magnets 162 are arranged radially around a central aperture with their long sides parallel to the spindle and their large-area faces adjacent each other. Sixteen spaced magnet pairs 166 are arranged, one between the outer ends of each pair of rectangular magnets, to form a series of hollow rectangular outer surfaces, the magnets 162, 166, all having their north poles directed outwards. Within each hollow rectangular surface is the south pole of one of sixteen further rectangular magnets 168.

In the magnet array 160, a plurality of tunnel magnetic fields is formed, the tunnels having rectangular axes or centre lines and the long sides of each rectangle being parallel.

It will be seen that if the array 160 is rotated about an axis through the central aperture each tunnel magnetic field in turn will be swept past an adjacent outside surface and at a set position, the effect will be to sweep a series of straight axis tunnel magnetic fields past the surface. A similar effect is achieved for a surface inside the central aperture as the inner face of the array 90 has the reverse magnetic poles to the outer face. A plurality of rectangular section tunnel magnetic

fields is thus formed both inside and outside.

Referring now to Figure 2, the array 90 is enclosed by an outer cylinder 92 and a double walled inner cylinder 94, the cylinders being joined by watertight end caps 96.

The array is arranged with its cylindrical axis vertical. One magnet 98 is shown. The magnet array has upper and lower caps 100, 102 which are grooved to carry ball bearings 104 which run in upper and lower bearings 106, 108. The lower bearing is carried by an annular support plate 110.

The upper face of the lówer bearing 108 has a deep annular channel 112 which accommodates a plurality of vanes 114 attached to the lower cap 100 and spaced around the magnet array. The lower face of the lower bearing 108 has a water supply channel 116 connected to a plurality of angled apertures 117 to the channel 112, and the supply channel 116 is connected to the inner pipe 120 of a coaxial pipe 118. The outer part of the pipe 118 is connected to the annular space of the double walled inner cylinder 94. A sputtering plate, which may be cylindrical or part cylindrical, is located within the inner cylinder 94 (and is not illustrated in Figure 2).

When cooling water is supplied through the inner pipe 120, jets of water emerge through the angled apertures 117 and strike the vanes 114, causing the magnet array to rotate on the ball bearings 104. Water passes upwards between the magnets, as indicated by the arrows, and passes down through the annular space of the double walled inner cylinder 94 to the outer part of the coaxial pipe 120, cooling the inner cylinder 94 which constitutes a cathode. The tunnel magnet fields on the inside of the magnet array 90 sweep across the cathode surface.

Figure 3 and 4 show a second embodiment in which the tunnel fields are swept by a reciprocation of a planar array of magnets. Figure 3 shows a magnet array and cooling fluid drive constituted as a multilayer sandwich.

A water feed and return lock 201 supports a stator plate 202 and is covered by a water baffle plate 203. A rotating vane and connecting rod assembly 204 are housed in items 202 and 203. A spacer plate 205 gives clearance for the connecting rod. A magnet array 206 provides the top layer of the sandwich.

It will be seen that cooling fluid, e.g. water, is circulated inside the elements of the sandwich so suitable seals and materials will be needed. These are well-known to those skilled in the art so only points of special care or difficulty will be identified.

Feed and return block 201 provides channels for water feed and return paths from a central connection 210. These paths, as indicated by the arrows, link with the paths in the stator plate 202. Water from central connection 210 enters cavity 220 of the plate 202. Part of the water flows through channels 211, 212 of block 201 to enter cavity 221 of plate 202. From cavities 220, 221 of plate 202 inclined bores such as 223, typically six in number, extend to a drive chamber 222. The bores 223, as shown by the arrows, produce inclined jets of water in chamber 222. A water feed baffle plate 203 closes cavities 220, 221. A rotatable vane device 241 fits into drive chamber 222 and is pivotted on axle 242 fitted in a bore 213 in block 201. The inclined jets of water in chamber 222, in operation, drive vane device 241 round. A bronze connecting rod 243 is attached eccentrically to vane device 241 at pivot 244 so that rotation of vane device 241 becomes reciprocation of connecting rod 243 and attached slide block 244. Slide block 244 is housed, for reciprocation, in slot 231 of plate 203 and recess 224 in plate 202. The stroke of the reciprocation is "S".

Two drive pins, 245, project from slide block 244 and through spacer plate 205. Plate 205 has a central slot 251 to accommodate the connecting rod 243 as it moves and also allows cooling fluid from chamber 223 to pass to array 206. Plate 205 also has upper surface channels 252, 253 to provide a return cooling fluid path from the array 206 to block 201 and connection 210 through two bores formed through by the stack of elements 201, 202, 203, 205, to the exit from the arrangement.

Array 206 is arranged to reciprocate over spacer plate 205 by the action of connecting rod 243 engaged by drive pins 245 in suitable bores 261 in the array 206. A housing, not shown, is provided to contain the cooling fluid and the elements 201 to 206. Array 206 is shorter than elements 201 to 205 by stroke "S" so that it can reciprocate in the housing. Conveniently the long sides of array 206 have "V" grooves 262 to receive stainless steel balls which are also received in the housing, not shown, so that array 206 can reciprocate smoothly while being supported by the balls and "V" grooves. Array 206 is constructed of galvanised iron sheet, for mechanical and magnetic reasons, and supports an array of ceramic magnets. This array is similar to that described for Figures 1 and 2, longer magnets, such as 265 and shorter magnets, such as 266, being arranged spaced apart with alternating polarity upwards as shown and the outer ring completed by link magnets 267. The joins between magnets are not shown and various detailed forms are possible. The ceramic magnets thus create the array of a plurality of tunnel magnetic fields on a plane base.

A central lengthwise slot 264 in array 206 conveys cooling fluid to the spaces between the magnets and outer lengthwise slots 262, 263, collect cooling fluid for return via channels 252, 253 as mentioned above.

A source of sputtering material, 207, is placed above the array as shown in Figure 4 to be within the plurality of reciprocating tunnel magnetic fields from the array.

In operation to erode material from the sputtering material source 207 the plurality of tunnel fields is swept back and forth over the source surface to provide a plurality of zones from

which material is eroded simultaneously, which zones overlap to give substantially uniform erosion from the surface.

The arrangements described have the advantage over those in which a localised tunnel magnetic field is swept in turn over different zones of the source surface that the whole surface area of the source can be active all the time because of the plurality of tunnel fields present at all times while a substantially uniform erosion rate is achieved because the plurality of sweeping magnetic fields produce a substantially uniform magnetic environment over the substrate as one field succeeds another in a particular zone.

Thus a very high erosion rate, related to the number of tunnel fields, is achievable while the source of material is eroded evenly to achieve maximum operational time and minimal down time for a given quantity of sputtering source material placed on the arrangement.

Another advantage compared with using a moving single localised field from zone to zone of a surface is that variations of performance with sputtering material type are reduced.

Figure 4 shows a cross section of the array in Figure 3 to assist in understanding the assembly. The drive is shown in both Figures as by the cooling fluid but clearly other forms of drive could be used. Electromagnetic influence through a suitable housing, as is used with some domestic central heating circulator pumps, could be employed so long as the feature of a plurality of tunnel fields all sweeping a surface at one time is achieved.

The planar array in particular can be made to any convenient size. No dimensions are shown but the appropriate dimensions and projections will be readily determined by those skilled in the art. The above-mentioned article by Elphick indicates the magnetic field strength and other operating parameters that may be used. A planar array is particularly useful for sputtering large flat surfaces, for example sheets of glass windows to provide a coating for solar reflection or other architectural purposes. The planar array can cope with large sheets and provide a uniform coat at higher speed because of the large area of sputtering source that can be eroded in a short time.

The arrangements described provide for a significant increase in the erosion rate of a sputtering source, proportional to the increase in the number of fields in action, while achieving uniform erosion, thus greatly increasing the potential sputtering rate of sputtering equipment when such arrangements are employed. Suitable sputtering equipment is well-known in the art.

Claims

1. A tunnel magnetron source magnet arrangement including an array of magnets to provide an array of a plurality of similar, side-by-side tunnel magnetic fields, means to support the array to apply the plurality of tunnel magnetic fields at a surface of the source, means to move said array and said surface relative to one another so that the plurality of tunnel magnetic fields sweep over said surface, the arrangement being such that the movement causes said tunnel fields to sweep over substantially all the surface area and any adjacent sputtering source surface providing a plurality of simultaneous erosion zones together producing substantially uniform erosion over the whole of the sputtering source.

2. A source magnet according to Claim 1 in which the array is planar, such as a flat plate, in which array magnets are assembled with an alternation of polarity.

3. A source magnet according to Claim 1 in which the array is closed, such as a cylinder, in which array magnets are assembled with an alternation of polarity.

4. A source magnet according to Claim 1 in which the means to move the array is one of a mechanical linkage from a motor, a drive through gears or other transmission device or electromagnetic action without contact.

5. A source magnet according to Claim 1 including cooling fluid drive technique according to UK Patent Application 8220270.

6. A source magnet according to Claim 1 in which the whole of the plurality of fields is arranged to sweep the whole surface of the electrode, as with a cylindrical array and cylindrical electrode, or adjacent fields are arranged to sweep in turn in a reciprocating manner over adjoining and overlapping parts of the surface, each part being subject to a field substantially uniform and without interruption.

7. A source magnet according to any one of the preceding claims to provide uniform erosion which is substantially continuous over the whole sputtering source.

8. A tunnel magnetron source magnet substantially as herein described with reference to the accompanying drawings.

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